Prospective motion correction of DW 3D-MS EPI using collapsed FatNav (cFatNav)

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TARGET AUDIENCE – Researchers and clinicians interested in prospective motion correction.

PURPOSE – The sensitivity to motion induces artifacts in DW 3D-MS EPI (1) is well known. Its increased volume acquisition time, compared to e.g. DW ssEPI, makes traditional retrospective motion correction approaches ineffective. In-plane retrospective motion correction has been presented (1), but cannot handle any out of plane movements. Image domain motion navigators using the spatially sparse signal of subcutaneous fat, FatNav, has previously been shown as a promising method for motion detection (2). In this work we combine a collapsed FatNav (3), comprised of a chemical saturation RF pre-pulse and three orthogonal EPI readouts, with DW 3D-MS EPI for prospective motion correction. A cFatNav module is played out at the beginning of each excitation and motion estimates are calculated and returned in time for the subsequent excitation. By this approach a ~5-10 Hz motion update rate can be achieved, at the cost of a ~5% scan time increase.

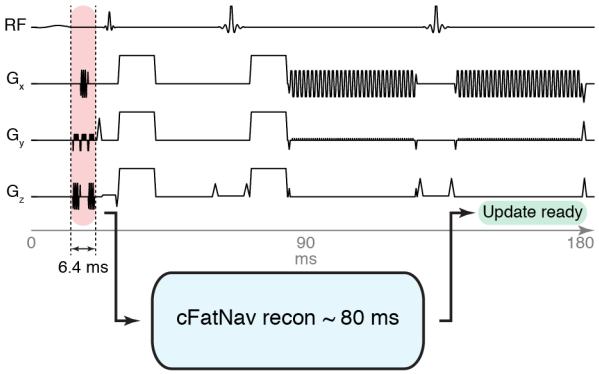

Figure 1. Pulse sequence diagram and cFatNav reconstruction timing

METHODS – All scans were performed on a 1.5 T clinical MRI system (DVMR450, GE Healthcare, Milwaukee, WI) using an 8-channel receive only head coil (Invivo Hi-Res Head Coil, Gainesville, FL). The DW 3D-MS EPI sequence was prescribed according to our default clinical protocol with relevant scan parameters being FOV 240×240 mm^2, matrix = 120×120, resolution = 2.0×2.0×2.0 mm^3, R = 2 (GRAPPA), TE = 79 ms, TR = 3200 ms, N_{Slabs} = 18, and $T_{Seq.}$ = 180 ms. Two 'b0' volumes were acquired in addition to six non-collinear diffusion-encoding directions (b = 1000 s/mm^2). The cFatNav was prescribed as follows; FOV = 320×320 mm^2, matrix = 48×48, resolution = 6.7×6.7 mm^2, R = 8 (GRAPPA), $TE_{Sag./Ax./Cor.}$ = 1.1/3.2/5.3 ms, $T_{seq.}$ = 6.4 ms. Calibration data for cFatNav were obtained by shifting k_{pe}-dephasing gradient for the R first acquisitions. Using the vendor´s reconstruction server, gradient delay estimation and GRAPPA weight estimation required ~0.5 s of computational time, in addition to ~0.25 s for building reference data sets for realignment. For the subsequent cFatNav data the reconstruction (including smoothing with a 20×20 mm^2 Gaussian kernel) required ~25 ms per projection. The pulse sequence diagram and cFatNav reconstruction timing can be seen in Fig. 1. Four i*n vivo* scans were acquired on a healthy volunteer. For the first two scans the subject was instructed to lie as still as possible. For the third and fourth scan the subject was instructed to move the head in a nodding motion on cue given by the operator. cFatNav data was acquired for all scans, but motion updates were only applied for scan two and four. Retrospective in-plane motion correction (1) was performed for all acquired data sets.

RESULTS – The cFatNav navigated DW 3D-MS EPI is shown in Fig. 2. In Fig. 2a-b the subject was instructed to lie as still as possible, and in Fig. 2c-d to perform nodding type head motion. From Fig. 2a-b it is clear that the motion estimates obtained when the subject was not moving were small enough not to introduce artifacts in the images. Comparing Fig. 2c-d the improvement of the prospective cFatNav motion correction is apparent, and image quality is almost as good as for the motion free cases.

DISCUSSION/CONCLUSION – By combining cFatNav and DW 3D-MS EPI we have taken a first significant step into a full rigid body motion corrected 3D diffusion-weighted imaging sequence. With prospective motion correction the DW 3D-MS EPI thereby becomes a more attractive choice in the clinical routine, where patient cooperation cannot be assumed (in terms of staying still). There exist, however, some jitter in the cFatNav data due to dissimilarities between the reference frame and realigned frames. This is due to the host sequence slab selection that nulls the magnetization for both fat and water, creating dark bands in the navigator projections. By adding the cFatNav readout block to a ChemSat module this prospective navigation approach can easily be ported to other pulse sequences, either as an addition to fat saturation or as pure navigation (by using a low flip angle for the saturation pulse).

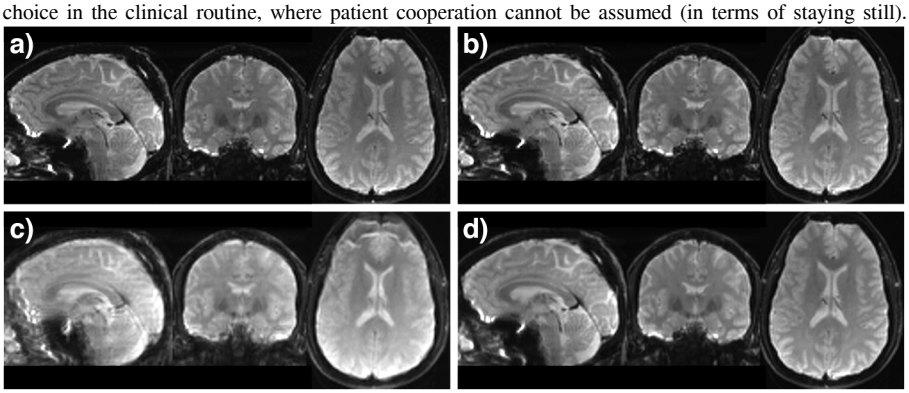

Figure 2. 'b0' DW 3D-MS EPI data with cFatNav. In a-b) was the subject instructed to lie as still as possible, while in c-d) to move the head in a nodding motion on cue. For a,c) was navigation data acquired but no updates made. For b,d) was motion detected and corrected for.

REFERENCES – [1] Engström et al. *Magn Reson Med* 2013 Dec;70(6)1507-14 [2] Skare et al. *Magn Reson Med* 2014 Apr. doi: 10.1002/mrm.25234 [3] Engström *ISMRM* 2014 p.1609